

# **ADVANCED CIVILIAN AERONAUTICAL CONCEPTS**

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## *ABSTRACT*

Paper discusses alternatives to currently deployed systems which could provide revolutionary improvements in metrics applicable to civilian aeronautics. Specific missions addressed include subsonic transports, supersonic transports and personal aircraft. These alternative systems and concepts are enabled by recent and envisaged advancements in electronics, communications, computing and "Designer Fluid Mechanics" in conjunction with a design approach employing extensive synergistic interactions between propulsion, aerodynamics and structures.

## *INTRODUCTION*

The last 50 years of aeronautics have been truly revolutionary. In much of the developed world, train and ship long haul passenger traffic has been replaced by aviation and aviation has assumed a dominant role in warfare. The list of revolutionary technological developments during this period includes large swept wing near-sonic transports of the 707 genre, supersonic cruise and fighter aircraft, turbojets and ramjets, high strength aluminums and composites, and a vast array of avionics. Much of this progress occurred under the dominant metric of higher and faster is better and was a continuation of aeronautical development trends since the early 1900's.

Today and for the foreseeable future, the metrics, and hence the nature of desired technological improvements are "different." These "new" metrics include COST, productivity (aircraft, airport/runway and air traffic control), safety and the environment (noise, pollution). Driving these metrics are global economic competition (exacerbated by the demise of the "cold war"), an increasing demand for air travel, increasingly stringent environmental regulations and the emerging competition from the ongoing telecommunications revolution(s) wherein business travel in particular may become increasingly replaced by "virtual" interpersonal interaction via holographic projection/virtual reality immersion, etc. Estimates indicate a 40 percent business travel reduction over the next 20 years due to this "teletravel" revolution with consequent (non-trivial) reductions (the order of 1000 units) in transport production. Such a reduction in business air travel would leave recreational travel the dominant market sector, which is extremely price sensitive and places a further premium upon cost reduction technologies.

The current approaches to these metrics almost universally involve incremental/evolutionary technological improvements to the existing paradigms coupled with revolutionary reductions in design cycle time and "manufacturability" improvements in the context of an "integrated product team." What are conspicuous by their absence are any major attempts to satisfy these metrics via the complementary approach of inventing, developing, and deploying advanced technologies, in particular advanced configurations, with revolutionary performance improvements. While traditionally performance improvements have been used to enhance speed or reduce fuel consumption, they can obviously also be employed to address the present metrics of cost/part count/weight,

productivity, safety and the environment, where advanced performance can have truly dramatic payoffs.

The purpose of the present paper is to discuss example advanced concept approaches, across the speed range, which may provide revolutionary changes in civilian aeronautics in the future. The context of this advanced concepts discussion is that there are no “magic bullets,” i.e., concepts which require no R&D, have no problems, require no research and provide guaranteed (huge) benefits. All of these approaches require considerable work to move them through the two filters which exist between an idea and a deployed system. The first of these filters is a technical one which asks the question “does it work.” The second, and immensely important, filter is technological and addresses the issue of whether the concept makes sense in the “real world” when all the “illities” are considered. Also, most of these concepts are not new, simply worthy of being readdressed in the context of new missions/requirements, available technology levels and implementation ideas. A central theme is the use of serious synergies between the propulsion, aerodynamics and structural systems (see reference 1).

### *DESIGNER FLUID MECHANICS*

Most of the configuration concepts discussed herein rely on a set of technologies developed extensively over the last 30 years which can be collectively termed “Designer Fluid Mechanics.” These technologies include laminar flow control (reference 2), mixing enhancement (e.g., reference 3), separated flow control (reference 4), vortex control (reference 5), turbulence control (e.g., reference 6), anti-noise, favorable wave interference (reference 7), and even “designer fluids.” In most cases, these have been taken to the flight test stage and beyond and are thus ready, in various manifestations, for inclusion in, and to provide enabling technology/ capability for, synergistic advanced aircraft concepts.

Consider, for example, the currently applicable aircraft metrics--productivity, safety, environment and cost. These would be greatly enhanced by major simultaneous reductions in wake vortex hazard, drag-due-to-lift and friction drag. Each of these issues has, thanks to the Designer Fluid Mechanics literature, an extensive array of alternative reduction approaches. If these various approaches are “merged” and “simultaneous solutions” sought, the resultant configurational implications strongly suggest revolutionary configurational alternatives, for the long haul subsonic transport case for example, to the current 707-DC8 CTOL transport paradigm. This serves to illustrate the thought processes followed to develop the advanced configurations described in the following sections.

### *ALTERNATIVE SUBSONIC TRANSPORT CONFIGURATIONS*

Strut/Truss-Braced Wings with Wing-Tip Engines--Pfenninger has long advocated strut bracing to improve the performance of conventional transports (reference 8). The structural benefits allow reduced wing thickness and sweep, resulting in a tremendously enhanced extent of low drag laminar flow, as well as increased span. Pfenninger's designs for such aircraft yielded L/D values in the 40's, over twice current levels. The concept was not, however, adopted primarily because the extensive wing span did not fit the FAA “80 meter box” for airport gate compatibility and disbelief that a transonic strut braced wing could be designed with acceptable shock drag. The latter objection is probably not valid in light of today's CFD capabilities. We have been too long constrained in aircraft design to linear theory and consequent “linear thinking.”

The span of a strut braced configuration can probably be reduced to the 80 meter requirement and the overall performance retained if an alternative approach is employed for major drag-due-to-lift reduction--wing tip engine placement (also enabled by strut/truss bracing). Whitcomb and others (e.g., reference 9) have shown that up to 50 percent DDL reductions are obtainable using this approach, which probably requires a third engine in the empennage region and utilization of thrust vectoring on all engines to handle the "engine out" problem.

The use of tip engines for drag-due-to-lift reduction is part of an overall paradigm shift in aircraft design where a configurational concept is sought in the context of an "open thermodynamic system," i.e., synergistic use is made of the energy added by the propulsion system. Historically, aerodynamic theory is almost totally predicated upon analysis within a "closed system" (no energy added within the control volume). Another (revolutionary) prime example of aero-propulsion synergisms is circulation control for high lift--capable of approaching the theoretical lift coefficient limit of  $4\pi$  vs. the values of 2 to 3 provided by the current variable geometry (slat/flaps) high lift approaches.

Double Fuselage--An advanced double fuselage approach could attempt to delete the outer wing panels (reference 10) and only retain a, largely unswept/long chord, wing section between the fuselages. This requires prodigious drag-due-to-lift reduction, a requirement which can be addressed via design of the fuselages as wing-tip "end plates" and the individual fuselage empennage as "winglets," i.e., thrusting surfaces in the presence of the wing tip vorticity wrapping around the fuselage(s).

For this case, the "midwing" can become the site of the gear (to allow use of conventional runways), engines "buried" at the rear of the wing to accrue the benefits of "boundary layer ingestion" and extensive (natural/ suction) laminar flow. The fuselages can also be made detachable to provide a civilian "sky-train" with enhanced productivity. The midwing portion which does all the "flying" can be in the air "around the clock" with freighter and/or passenger modules. Obviously, military versions could have cargo, troop, and refueling fuselages--providing a quantum jump in flexibility and productivity.

An alternative configuration is a "back-to-the-future" relook at a near-transonic biplane (reference 11). Recent work indicates a large and wide spectrum benefit suite for such an approach, again in the context of present-to-future advances in CFD, materials, controls, etc. technologies. The ring wing is also worth revisiting.

Spanloaders/Blended Wing Bodies--The emerging requirement for/interest in "jumbo-aircraft" and the success of a "deployed version," the B-2 bomber, has renewed interest, worldwide, in spanloader/blended wing-body aircraft (e.g., reference 12). The major performance benefits of such aircraft are required, zeroth order, to address the potential "killer issues" for jumbo aircraft of noise and vortex hazard engendered by their great weight. It is not clear, although jumbo aircraft will obviously hold more passengers individually, whether airport passenger throughput will go up or down with the introduction of jumbos.

Obvious benefits of spanloader aircraft include large increases in L/D (due primarily to the demise of fuselage wetted area/skin friction) and reduction in empty weight. The design approach "puts the lift where the load is" for a requisite size aircraft with a physical wing thickness sufficient to allow passenger seating within the wing. Work on such configurations is ongoing in the U.S., Europe, and Russia with an emerging consensus regarding at least a "local optimum" configuration.

## *HIGH SPEED CIVIL TRANSPORT*

The increasing importance of “Pacific Rim” air travel and the requisite long transpacific flight times for the current subsonic transports have renewed interest in a Mach 2 class “high speed civil transport.” Such a device is nominally a “flying fuel tank” to a much greater extent than for the subsonic case, due to the addition of appreciable wave drag. This large fuel fraction (order of two thirds of gross takeoff weight) makes the designs exceedingly sensitive to drag level and drag reduction. A mere 1 percent drag reduction can yield a 24 Klb reduction in take off weight. To first order the cruise drag is nearly equally partitioned between skin friction, volume wave drag and wave/vortex drag-due-to-lift. Large drag reductions are again available via “Designer Fluid Mechanics,” e.g., laminar flow control, favorable wave interference and flow separation control as well as configuration tailoring to produce an elongated lifting line (reference 7). The following advanced configuration concepts provide enhanced performance alternatives to the conventional “double-delta” planforms. Drag reductions theoretically attainable include up to 70+ percent of the skin friction via laminar flow control and a very large fraction of the volume wave drag via favorable wave interference.

**Parasol Wing**--This is an old approach wherein reflections of the fuselage nose shock provides favorable interference lift and subsequent afterbody region thrust (reference 13). Estimated L/D improvements are in the range of 25 to 30 percent. Advanced technologies required to accrue these benefits include flow separation control for the shock-boundary layer interaction regions and fluidic or variable physical geometry to work the “off-design” issues.

**Strut-Braced “Extreme Arrow”**--Pfenninger has also advocated an externally strut-braced HSCT with truly revolutionary cruise performance--an L/D of order 20, over twice that of the best of the current approaches (reference 14). The strut bracing allows use of an extreme arrow wing planform with minimal wave drag-due-to-lift and extensive laminar flow (“controlled”). Mid-wing fuel canisters are used to provide favorable wave interference and load alleviation with extensive “natural” laminar flow on both the fuel canisters and the fuselage.

**Other Alternative HSCT Approaches**--Northrup has studied a “reverse delta” configuration for purposes of obtaining extensive regions of “natural” laminar flow on the wing (reference 15). Some “novel” general concepts with application across the configurational spectrum include use of flow separation control at cruise to allow full exploitation of inviscid design precepts (reference 7). Benefits include enhanced wing leading edge thrust, increased upper surface lift, increased fuselage lift/camber (reduced wave DDL) and enhanced performance of favorable wave interference (via shock--B.L. separation control).

Another “alternative” is to consider a “multi-stage” aircraft (reference 7). In-flight refueling is one way to “multi-stage,” but what is specifically suggested herein is that since the HSCT is a “flying fuel tank” the aircraft that lands is very different/lighter weight than the vehicle at takeoff. Therefore, the heavy fuel/noise control/high lift and gear required for the “takeoff” condition could be positioned toward the rear of the craft and “detach”/“fly back” once airborne. The vehicle is thus not burdened throughout its flight by apparatus uniquely required for mission initiation only.

If economics or environmental considerations dictate a lower altitude/lower speed (<sup>a</sup> 50 Kft, M <sup>a</sup>1.5) than an obvious “approach of choice” would be the R.T. Jones yawed wing (reference 16) which is capable of doubling speed and increasing PAX load-out 25 percent vis-a-vis the 747 for essentially the same fuel burn.

## *PERSONAL AIRCRAFT--THE VTOL "CONVERTICAR"*

The developed nations entered the 1900's with a transportation system (for people) centered upon the horse, the railroad and the steamship, with associated travel times the order of hours-to-days/weeks, depending upon distance. In the closing years of the same century, the automobile has long supplanted the horse and the fixed wing aircraft has nearly driven the railroads and steamship companies from the long haul passenger business. Travel times have shrunk to minutes-to-hours. In the process of supplanting older transportation systems, these newer approaches have had a profound influence upon the structure of modern societies. In the U.S., cities have expanded out of 18th century seaports and 19th century railheads, where much of the developed region was within walking distance of the transportation terminals, into tremendous suburbs with attendant reductions in crowding/increased opportunity for individual home ownership etc., etc. The existing transportation system fulfills a variety of purposes, including travel to and from work and stores, and for various business, service and pleasure related activities.

This portion of the present report will center upon future possibilities/options for a specific portion of the transportation spectrum, short-to-moderate range, nominally from 10's to 100's of miles. The current dominant transportation mode for this mission is the automobile, which, possibly more than any other single technical achievement, has enabled the current life style enjoyed by the developed nations. In this process, the auto has created massive safety problems and been responsible for the expenditure of truly prodigious sums on roads and bridges, and pollution-induced health and material degradation. The current status of the auto infrastructure is that we continue to clear and pave more of the watershed, contributing to flooding, desiccation and the formation of heat islands. Also, the average trip time is increasing due to expansion of the suburbs and increased congestion, causing non-trivial changes in family life as travelers attempt to utilize non-traditional time slots, or suffer long/nonproductive commutes. In the U.S. the interstate highway system is (finally) finished and is already clearly overburdened and in need of very expensive repairs and expansion.

Society cannot, easily or otherwise, continue to bear the costs imposed by almost sole reliance upon the automobile for short-to-intermediate passenger transport, alternatives are necessary for the future--both for the developed societies and those that desire to/are developing. Probably the most commonly advocated alternatives involve some form of mass transit, which have, along with tremendous capital costs, several other drawbacks such as passenger wait time, weather exposure and lack of privacy, security, pride of ownership and personal stowage. Additional drawbacks are the fact that they are not portal-to-portal and there is no guarantee of having a seat as well as an inherent assumption regarding increased population density/concentration. Undoubtedly, the future mix of short-to-intermediate transport systems will include both mass transit and automobiles of some variety, probably operated on "intelligent" highways to improve safety and throughput/trip time (reference 17).

There is, however, both a need and an opportunity to include in the transportation mix a personal air vehicle which would provide, percentage-wise, the same increase in speed (compared to the auto in traffic), as the auto has provided over the horse. Personal air transportation is both revolutionary and the next logical step in the development of human infrastructure and corporal communication. The increased speed of such a capability, along with the greatly reduced capital requirements in terms of highways/bridges, etc., should allow significant increases in the quality of life as well as reduced state and national public works budgets. Specific benefits include distribution of the population over a much larger area allowing a more peaceful/less damaging co-existence

of man and nature, along with improved transportation safety. The “vision” is of multilevel highways in the sky, controlled and monitored by inexpensive electronics as opposed to narrow, single level, exceedingly expensive “ribbons of concrete” (e.g., reference 18). Such air systems/vehicles could also obviously be used for longer haul, as are automobiles today. The various wait times associated with commercial air travel, along with the inefficiencies in terms of transit time of the hub and spoke system mitigate in favor of reduced overall trip time for slower, but more direct, travel via personal aircraft (compared to the “faster” commercial jet). Various options exist for personal aircraft systems. The discussion herein will address one such option, a VTOL-converticar, and attempt to defend that particular recommendation.

Certain requirements/desirements are common to any personal transportation vehicle/system. These include short transit time/high speed, direct portal-to-portal, privacy and security, constant availability, personal stowage and a suitability for use by the “non-pilot.” The latter necessitates from the outset an obvious (and probably attainable) goal should be an automatic personal air transport system, automatic with respect to navigation (e.g., references 19-21), air traffic control and operation. The technology to accomplish this is either currently employed by/for the long haul air transport application, or in the research/application pipeline, thanks to the microchip “electronics revolution” and includes GPS, personal communication satellites and the military investments in RPV’s, AAV’s, UTA, etc. Such automatic operation provides vastly improved safety, as the preponderance of accidents are due to operator error. In addition, it makes personal air vehicle transportation available to the general public, as opposed to the few who have the opportunity, wealth, and physical characteristics to become pilots, as well as reducing the unit cost by an order of magnitude due to the concomitant vast increases in production rate/market.

Conventional wisdom holds that, to be successful, an alternative transportation system must be not only faster, but also relatively inexpensive. The costs involved in any system include acquisition, operation, maintenance, and depreciation. To be competitive with the automobile a personal VTOL-converticar should have an acquisition cost in the vicinity of a quality automobile. Although in terms of the current helicopter industry, this is a ridiculous target, the advantages of a production run of millions instead of hundreds, along with a recent offering of a single seat helo for \$30K (references 22 and 23) and a two-place “gyroplane” for \$20K, all at small production runs makes the outlook to achieve such a goal possible if not probable. Operational costs include fuel, insurance, parking fees, etc., and need not be greater than the auto. Maintenance is considerably greater for present helos than for autos, and therefore this issue would have to be addressed in any personal helo technology development program.

All-weather operation is also a requirement, the same all-weather capability one now has in an automobile, which is by no means absolute. Heavy rain, and extreme winds, ice and snow will all either slow or stop the auto, and similar restrictions will hold for the personal helo. Obviously the evolving “detect and avoid” technology could be utilized by the personal helo (either on or off board) to increase safety vis-a-vis extreme weather. In terms of speed and range, the helo must provide a significant speed advantage or it is simply not viable. As compared to a fixed wing personal aircraft, the helo speed advantage is much less vis-a-vis the auto, but at a nominal factor of 4 (for the traffic case) still sufficient. We are currently spending significant sums to gain a factor of 2+ in the high speed civil transport program (vis-a-vis subsonic transports). Another key issue is rider acceptance in terms of acoustics, vibration, ride quality, and reliability/safety. All of these technical areas will require further work, although the helo community has made significant strides in these already and considerable further gains/technological advances are

in the pipeline. A final major set of issues involve community acceptance in terms of acoustics and downdrafts during near surface operations. Again, more work is needed, but these could be addressed by operational as well as technological approaches. Previous approaches to the "personal helicopter" have mainly considered existing machines as opposed to the advanced technology/farther term vision discussed herein (e.g., references 24-26). There have been, however, calls for such an approach (references 27, 28).

Over the years, particularly since the 1930's, there have been suggestions, and in some cases strident calls, for the development and marketing of personal aircraft. Although "general aviation" has made considerable advances, the "aircraft for the masses" never really caught on for a variety of reasons, mainly involving COST, requisite technology readiness and a requirement that the "operator" be a "pilot," e.g., non-automatic operation. History is replete with examples of concepts which are good ideas and which keep resurfacing until the technology base is ready. An obvious example is the gas turbine engine. Since the last personal aircraft campaign in the late 40's-50's, major strides have occurred in several enabling technologies. These include light weight, miniature, inexpensive and tremendously capable electronics/computing, lightweight composite materials with essentially infinite fatigue life, computational fluid mechanics, smart-to-brilliant materials/skins, flow control of several types and active controls/load alleviation. Such advances significantly change the personal aircraft discussion, particularly for the helo. "The helicopter looks, 35 to 40 years after its invention, to be poised in the position the fixed wing aircraft were in the late 40's and early 50's, again 40 years after the first flights were being made" (reference 29). In particular, the personal helicopter would profit from much of the sizable investment made in military machine research, albeit the civilian application is in many ways less severe in terms of "rough usage" etc. This is again directly analogous to the fixed wing situation where the 707 class of transport aircraft profited immensely from/was enabled by, the military investments in swept wing/jet propelled bombers/tankers/transport.

Key helo-specific technologies either available or in the pipeline include composite blades with 10,000 hour fatigue life, the hingeless-bearingless rotor with low drag hub, automatic health monitoring to allow significant reductions in maintenance costs, anti-vibration and anti-noise for enhanced rider comfort, automatic piloting and navigation/nap-of-the-Earth operation, and composite structure and smart skins for flow and load control (see, for example, references 30-37).

There are several "systems level" issues and critical choices regarding the personal aircraft which served as key discriminators in the selection of the particular personal aircraft discussed herein, a helo-converticar. The first such issue is whether the personal aircraft (either "fixed" or rotary wing) should be a separate air vehicle, or a "converticar," i.e., a combination automobile and air vehicle capable of economically performing both missions. Economics and utility strongly favor the "converticar" option. There are numerous elements common to both the air and ground vehicles, such as passenger compartments, engines, etc. and therefore, if it is technically feasible to reduce the weight of an auto to what is reasonable for an air vehicle, then a single device should be considerably more economical (initial cost as well as maintenance-wise) than buying and maintaining two separate vehicles, particularly when one considers the present cost of autos. Simplex estimates of the flight-specific component weight indicate a value of less than 1000 pounds, indicating that, with shared utilization of common systems such as the engine, the "all-up" weight of the converticar could be in the (reasonable) range of 2600 to 3000 pounds. From an operational viewpoint, usage as well as maintenance-wise, a single vehicle should be much more convenient. Once the converticar option is selected, some decision/recommendation has to be made regarding the provision for the "air-unique"

components, particularly the lift-producing surfaces which require, for reasonable levels of drag-due-to-lift, non-trivial span/aspect ratio. Options include towed “trailored” wings (utilized in early versions of the converticar), fixed wings of inherently low aspect ratio for “roadability” (reference 38), airport “rent-a-wing” concessions where the wings are attached prior to, and removed at the conclusion of, flight, and telescoping wings. The present author favors the telescoping option as offering the best compromise between convenience and performance.

The next critical choice is between conventional/“fixed wing” operation and a VTOL device. An essential difference is that the fixed wing machine/operation requires an airport. There are many thousands of GA airports in the U.S. and one would have to begin and end the air portion of the trip at one of these. In the opinion of the present author, this is simply too restrictive and contravenes several of the fundamental purposes of the personal air vehicle such as independence of/reduced requirement for large civil works, portal-to-portal transportation, and access to remote sites (remote from roads, etc.). The VTOL option would allow development/usage of currently undeveloped nations/regions at a fraction of the cost of the roads/bridges, etc. usually required for such development, and at much less disruption to the environment (reference 39). Conversion from ground to flight and back again for a helo-converticar requires only a relatively hard surface with a diameter the order of 25 ft., something which could be placed at intervals alongside the existing highway system to provide convenient ground-to-air “merging” away from existing builtup housing areas to minimize acoustic/downdraft etc., influences upon the population. Further advantages of the helo include the provision for both lift and propulsion in a single device during air operation and ATC “margin” (in the event of an ATC conflict the vehicles involved could “hover” or land while the problem is addressed/resolved).

Another major option involves the extent to which the operation in the air mode should be automatic as opposed to pilot/human derived. While sport models could be somewhat human-controlled (within the confines of the ATC/safety regulations) the optimal solution is clear. The portion of the population physiologically capable of becoming pilots is not large and there is considerable cost and time involved in doing so, most accidents are due to pilot error (reference 40), and the ATC system requires, for the large numbers ultimately envisaged, automatic operation. Therefore, a user-orientated personal air capability should, ultimately, be automatic in operation as well as navigation and ATC, as already suggested herein.

A personal transportation machine capable of both ground and (VTOL) air operation could be an automobile with an IC engine (reference 41), probably initially a two-seater and at least somewhat pilot-controlled, which is light enough to also fly and which has built into its roof an erectable low drag, large taper (reference 42) rotatable hub with a diameter consistent with the vehicle width containing the order of four or more telescoping rotor blades. In addition, a rear deck vertical fin is required within which is a, perhaps electrically driven, tail rotor. Alternative approaches include circulation control on the “afterbody” or a tandem/counter-rotating rotor system. As stated several times in this discussion, the central issue is COST (see the quote from Henry Ford in reference 43) and usability. As a result of technological advances in several areas, many of them momentous, and the tremendous requirement/market for such an affordable/user-friendly capability, the issue of personal air transportation should be revisited. The probable course of development for personal air transportation is parallel to that of the automobile in the early 1900’s. The initial machines were expensive (“rich man’s play toys”) with many impediments to their operation such as poor roads, noise sensitivity and laws which were in many cases “anti-automobile.” Once industrialists (e.g., Henry Ford) addressed the problem via “design to cost/PRICE,” simplicity (any color as long as it’s black) and mass



production, the price dropped drastically and the resulting widespread sales/utilization of the product revolutionized, in many ways, our entire society (see also reference 44).

### *SUMMARY*

Advanced configuration aeronautics is long term and high risk but need not be expensive and is, in the opinion of the author, the only approach available which can seriously satisfy the current/future metrics of productivity, cost, safety and environment in a truly meaningful manner. Contained within the discussion herein are several relatively novel/general approaches/concepts in that regard (other new/newer contributions are specific to a particular configurational approach).

1. Transport aircraft designed in an open thermodynamic system--i.e., utilization of extensive propulsive/aerodynamic synergisms.
2. Flow control at cruise and otherwise to accrue full inviscid performance benefits.
3. Automatic personal aircraft operation (via GPS, DBS/personal coms satellites and RPV/AAV technology) enabling a large vehicle production run and an affordable revolution in personal mobility and many aspects of our culture/economy.
4. A return to utilization of performance as a way to work affordability (along with design cycle and manufacturability/"process").

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